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FINAL REPORT
on
"Digital Landsat Data Analysis of Tenn."
Contract #NAS8-33218

Prepared by
the
Remote Sensing Division,
University of Tennessee Space Institute
UT #R02-400224

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THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE
TULLAHOMA, TENNESSEE 37388
615/455-0631
Graduate Education, Research, Postdoctoral Study
and Continuing Education in the Aerospace Sciences

March 28, 1980

Mr. A. D. Smith
AT01
National Aeronautics and Space
Administration
George C. Marshall Space Flight
Center
Marshall Space Flight Center,
Alabama 35812

Dear Mr. Smith:

Enclosed are 30 copies of our Final Report on Contract #NAS8-33218, "Digital Landsat Data Analysis of Tennessee".

If anything further is needed, please contact me.

Sincerely,

Dr. F. Shahrokhi
Professor and Director
Remote Sensing Division

FS:ld

Enclosures: 30 copies of Final Report to be distributed as follows:

AT01	26 copies
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DIGITAL LANDSAT DATA

ANALYSIS OF TENNESSEE

ABSTRACT

The development and demonstration of a system for digital analysis of Landsat data is described. This was designed to fulfill specific requirements of Tennessee state government agencies, liaison with which is also described. A sample land-use map is included. Computer compatible tape formats are listed, and the necessary reformating explained. Software development is discussed, and the hardware system based on a Cal Data I minicomputer is outlined in detail. A need for improvements as recommended by another NASA contractor is discussed. The appendix gives details of Tennessee agency concerns.

DIGITAL LANDSAT DATA
ANALYSIS OF TENNESSEE

INTRODUCTION

Planning is a systematic process of formulating objectives for future conditions by gathering and analysing data of past and present conditions and applying the gathered information to achieve certain objectives in the future. Landsat data has proven to be a very useful tool in providing information that is useful to planners, and it is for this reason that more and more planning agencies are making use of these data. The synoptic view (one frame covering over 30,000 square kilometers and repetitive coverage (18 days) and the multispectral nature of these data makes it particularly useful for regional planning purposes. The Landsat data has found its utility in multiple fields such as agriculture, geology, hydrology, and land-use throughout the world.

In the State of Tennessee the University of Tennessee Space Institute (UTSI) has been actively engaged in research and applications oriented programs to demonstrate utility of remote sensing data to the potential user agencies. The various studies that have been conducted at UTSI under NASA and other contracts include; (a) Remote Sensing of Earth Resources and Environment, (b) Land-use Classification and Mapping, (c) Remote Sensing Application to Wetlands, Agriculture and Forestry, (d) Applying NASA Remote Sensing Data to Geologically Related Regional Planning Problems, (e) Remote Sensing Application to Highway Planning,

(f) Application of Landsat Data to Mining and Land-use Planning, and (g) Use of Remote Sensing Technique in Evaluating Earth Resources. Most of these studies have been conducted by employing manual photo-interpretation techniques and using optical and electro-optical interpretation equipment.

The Landsat Multispectral Scanner (MSS) data is originally recorded on High Density Digital Tapes (HDDT's) which in turn are converted into computer compatible tapes (CCT's) and film products. In the process of converting digital data to film products obviously some information content is lost. This is one reason more emphasis is being put on digital analysis techniques of Landsat data.

There are two distinct advantages favoring digital analysis of Landsat data. One is that digital data is the original data without any degradation and the other is high speed of present day digital computers which can process huge bulks of data in a relatively short time. However, the biggest disadvantage of computer processing is the high skill and higher expenditures involved. Processing of a single Landsat frame may cost thousands of dollars, which may be prohibitive to many users of the data.

A low cost data analysis system is the one alternative and the principal objective of this study has been to demonstrate the possibility of such a system by analysing Landsat digital data of Tennessee and inclusion of such a system into state information systems. Recently NASA has transferred a software program NRPAS (Natural Resources Planning Aid System) to TSPO (Tennessee State Planning Office) for information retrieval. The system that has been developed at UTSI is designed to provide information to NRPAS as well as non-automated users.

During the past several years UTSI has been providing its technical expertise and laboratory facilities in remote sensing to popularize the use of this new technology and is thus playing a key role for transfer of technology from NASA to the State of Tennessee.

COORDINATION WITH OTHER AGENCIES

As per objectives of this study an active liaison was maintained with the various State agencies throughout the span of this study to incorporate their information needs into the data analysis procedures. The immediate requirements of the various agencies of the Tennessee State Government for digital Landsat data analysis and data base participation were examined. The Appendix presents a list of requirements of the Tennessee State Government. In addition, an active liaison was also maintained with the other NASA contractor, Metrics, Inc. Their advice and recommendations were incorporated while conducting this study.

DESCRIPTION OF LANDSAT SENSORS

Landsat satellites are equipped with two separate sensor subsystems which produce imagery of the Earth's surface in several spectral bands. These sensor systems are (a) Return Beam Vidicon Cameras (RBV) and (b) Multispectral Scanner (MSS).

The RBV subsystem in Landsat 1 and 2 contained three individual cameras operating in different nominal spectral bands from 0.475 to 0.830 micrometers. On Landsat 3, the RBV system has been modified and contains only two panchromatic cameras. These panchromatic cameras produce two side by side images rather than three images of the sames area as produced by three independent cameras on Landsat 1 and 2. Each camera covers an area 99X99 km^2 with an instantaneous field of view (IFOV) of about 19 meters. Each RBV image is referred to as a subscene, the four subscenes that comprise a Landsat scene are labeled A, B, C, D. The four RBV images approximately coincide with one MSS frame.

The MSS in Landsats 1, 2 and 3 is a four band scanner with six detectors in each spectral band. A fifth band on Landsat 3 known as the thermal band is not functioning at this time. The MSS is a scanning device which uses an oscillating mirror to scan over lines perpendicular to the spacecraft ground track. The surface of the earth is imaged in four spectral bands through the same optical system, so that optical energy is sensed simultaneously in the four bands, 0.5 - 0.6, 0.6 - 0.7, 0.7 - 0.8, and 0.8 - 1.1 micrometers respectively. The cross track ground coverage of 185 km is obtained as the flat mirror oscillates

2.89 degrees at a rate of 13.62Hz. During each mirror cycle, six lines of 79 meters width are scanned, and hence the line scanned by the first detector in a cycle is adjacent to the sixth line of the previous cycle. The instantaneous field of view of 79 meters square on the ground is delineated by square input end of each optical fibre. The area sampled to form the reflectance data for each picture element (pixel) is 624 square meters. Along a scan line the sampling rate is approximately 100,000 Hz, which results in overlap of the samples along the scan lines such that effective area covered per sample is 1.1 acres.

LAND-USE CLASSIFICATION OF TENNESSEE FROM LANDSAT AND AERIAL PHOTOGRAPHS

As a preliminary to establishment of a satellite data input capability for the Tennessee data bank, land-use for the whole State was interpreted to level II from Landsat and aerial photographs keeping in view the specific information requirements of various user agencies. West Tennessee has been interpreted and mapped, while maps of the other two Grand Divisions of the State are in the draft stage. The land-use classification of Tennessee was done with two purposes in mind. Firstly, the results from this effort have been distributed to the Tennessee State agencies and a preliminary benefit from such interpretation, mapping and distribution is the correction and amendment process which is thereby begun, with comments from users to be obtained after experience has been gained in applying the data. Secondly, it would create an initial universe of corrected data from which samples can be drawn at random, stratified or unstratified, for checking the reliability of automatic digital mapping.

A copy of an example of the land-use map is attached as a separate fold-out, Figure 1.

DESCRIPTION OF TEST SITE

Initially it was intended to carry out the present study for the whole State of Tennessee, but due to constraints of funds available in this study and the prohibitive costs of CCT's only one scene could be included. Fig. 2 shows, in the shaded area, the location of this scene.

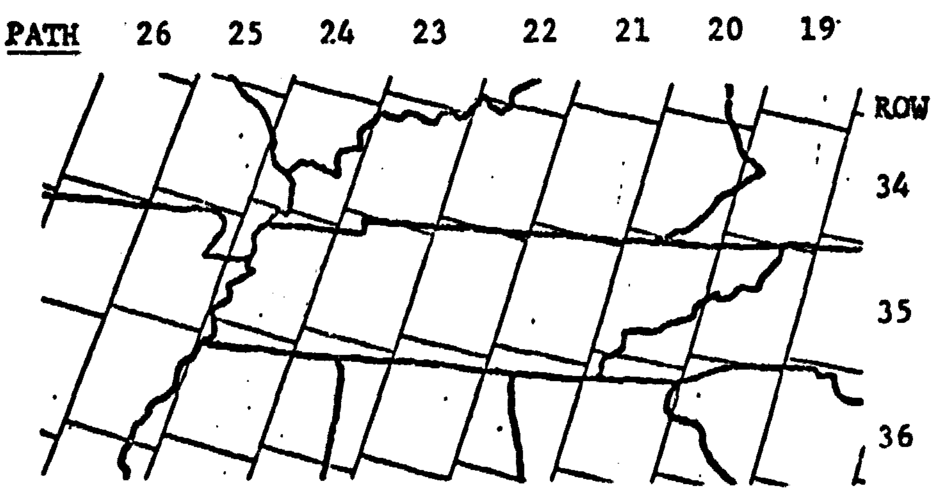

FIG. 2. LANDSAT SCENES OF TENNESSEE

ACQUISITION OF DATA

Landsat-3 was operational at the time the study started, but due to the fact that Landsat-3 data was not readily available Landsat 1 and 2 data was selected. MSFC was requested to lend CCT's of Tennessee that might be available. In response to the request MSFC located and sent two scenes; 1070-16055 and 1286-16055 (024-035). Both of these were in 4 reel, 9 track, 1600 bpi format.

DATA FORMAT OF EDIPS CCT'S

The EROS data center formerly produced computer compatible tapes (CCT's) of Landsat MSS data in 1600 bpi and 800 bpi formats. Both of these were geometrically uncorrected and a geometric correction had to be applied before any further processing could be done.

But recently the EROS data center has changed their classification of CCT's. The CCT's produced by EROS Data Image Processing System (EDIPS) are now classified by two major data distinctions: sensor type (RBV, MSS), and whether or not geometric corrections have been applied to be image data. Presently four types of CCT's are available:

CCT-AM: partially processed MSS data (without geometric corrections applied)

CCT-PM: fully processed MSS data (with geometric corrections applied and resampled to a map projection)

CCT-AR: partially processed RBV data (without geometric corrections applied)

CCT-PR: fully processed RBV data (with geometric corrections applied and resampled to a map projection)

These CCT's can be produced in either a band interleaved by line (BIL) or a band sequential (BSQ) format and in either 800 bpi or 1600 bpi densities. (See reference 1.)

REFORMATING OF CCT's

The CCT's borrowed from Marshall Space Flight Center were in a band interleaved format. The entire scene on such tapes is segmented into four parts each on a CCT. Each tape contains an identification and annotation record, followed by the data in eight-bit bytes. The annotation record contains the information regarding the conditions of exposure, such as date and time, sun elevation, coordinates of the image center, locations of the lines of latitude and longitude intersecting the image. Data values in the four channels form pairs of adjacent pixels are interleaved according to the following order of channel numbers 44 55 66 77. The CCT's had to be reformated using the computer facility at Knoxville so as to contain data in a band sequential format, facilitating the grey scale printouts in each spectral band.

SOFTWARE DEVELOPMENT

The necessary first step for processing digital data of a scene is the identification of data segment required based on some reference system such as latitude and longitude and then somehow view the data visually to make sure that the area of interest has been selected. This can be done either by a grey scale printout or by display on a Cathode Ray Tube (CRT). (See reference 2.) In the present study both of the techniques were used to select a particular data segment, by developing suitable computer programs.

The data so selected may be transferred to another magnetic tape to be used in subsequent operations.

Classification algorithms are a series of mathematical operations which determine from a set of measurement the class or type of object which is being measured. The mathematical criteria which are employed in classifying the feature vectors are called decision functions. A series of computer programs have been developed during the course of this study which first identify a particular data segment and then carry out feature classification by employing certain mathematical algorithms. The main program which carries out all these operations has been named RESIS. This program can be implemented on a minicomputer of 32K core/one magnetic tape drive capacity and is presently resident in the UTSI Remote Sensing Laboratory files. RESIS supports its own set of application routines by which data is processed prior to being inducted to a selected geographical data base. The UTM coordinate system is the final reference coordinate system for data storage and retrieval.

HARDWARE SYSTEM

As shown in Figure 3, the UTSI digital capabilities are centered in an inhouse dedicated computer. This system, a Cal Data I Computer System, is a 16 bit machine with a cycle time of 850 nanoseconds. The CPU operates a set of microprogrammed sequences stored in a control memory section. These may be altered to provide modified or additional instructions if necessary. All peripherals on the Cal Data are attached to a bi-directional bus shared by all elements of the system. The present configuration supports 48K words of mapped memory. An extended instruction set allows for extra manipulation of floating point numbers including hardwired multiply and divide. System programs are provided for this machine as well as the FORTRAN IV, BASIC, and MACRO programming languages.

The system console is the Decwriter II by DEC. This terminal allows on or off-line operation at a rate of 30 characters per second (300 baud).

The random access storage devices for the system consist of two Wangco 100 TPI Series T magnetic disk drives and accompanying controller. Each drive incorporates a permanent disk as well as a removable cartridge of the IBM 5440 type. Each platter has a capacity of 2.5 megabytes and is treated as a separate device by the system. Thus, maximum on-line disk storage provided is 10 megabytes.

A Digi-Data 1730 magnetic tape unit and controller provide the ability to work with large sequential files as well as to archive such data as maps or photos. The unit operates at a speed of 45 inches per second and can read 9 track IBM or DECformatted magnetic tape at either 800 or 1600 bits per inch. The transport uses tension arms to handle the tape and provides power-fail protection capabilities.

A Versatec 2160A Matrix Printer/Plotter carries out most of the system's production of maps. The Matrix uses an electrostatic writing technique with only two moving parts. The writing is accomplished by varying the voltage applied to a linear array of conducting nibs under program control. The position of the charge thus placed on the paper becomes visible as the paper passes through a liquid toner bath.

The Matrix offers printing, plotting, or simultaneous print/plotting capabilities. In print mode it is driven by the line printer handler of the operating system program. For plot mode an extensive software package, Versaplot I, is in use. These routines provide the capabilities of line drawing, lettering and toning used in map production.

The entire non-digital portion of the system also shown in Figure 3, was developed by Interpretation Systems Incorporated (ISI). A Sierra Camera and control unit equipped with a select quality black and white vidicon tube inputs the analog photo data. The tube converts the amount of light passing through each point on an image to an output signal. A light table is provided so that transparencies may be backlighted.

An ISI VP-8 Image Analyzer is a multipurpose device which provides level-slicing of the input voltage, area calculations for each slice, and the generation of a vertical and horizontal cursor line pair. These cursors allow the user to specify a particular point of interest on the image.

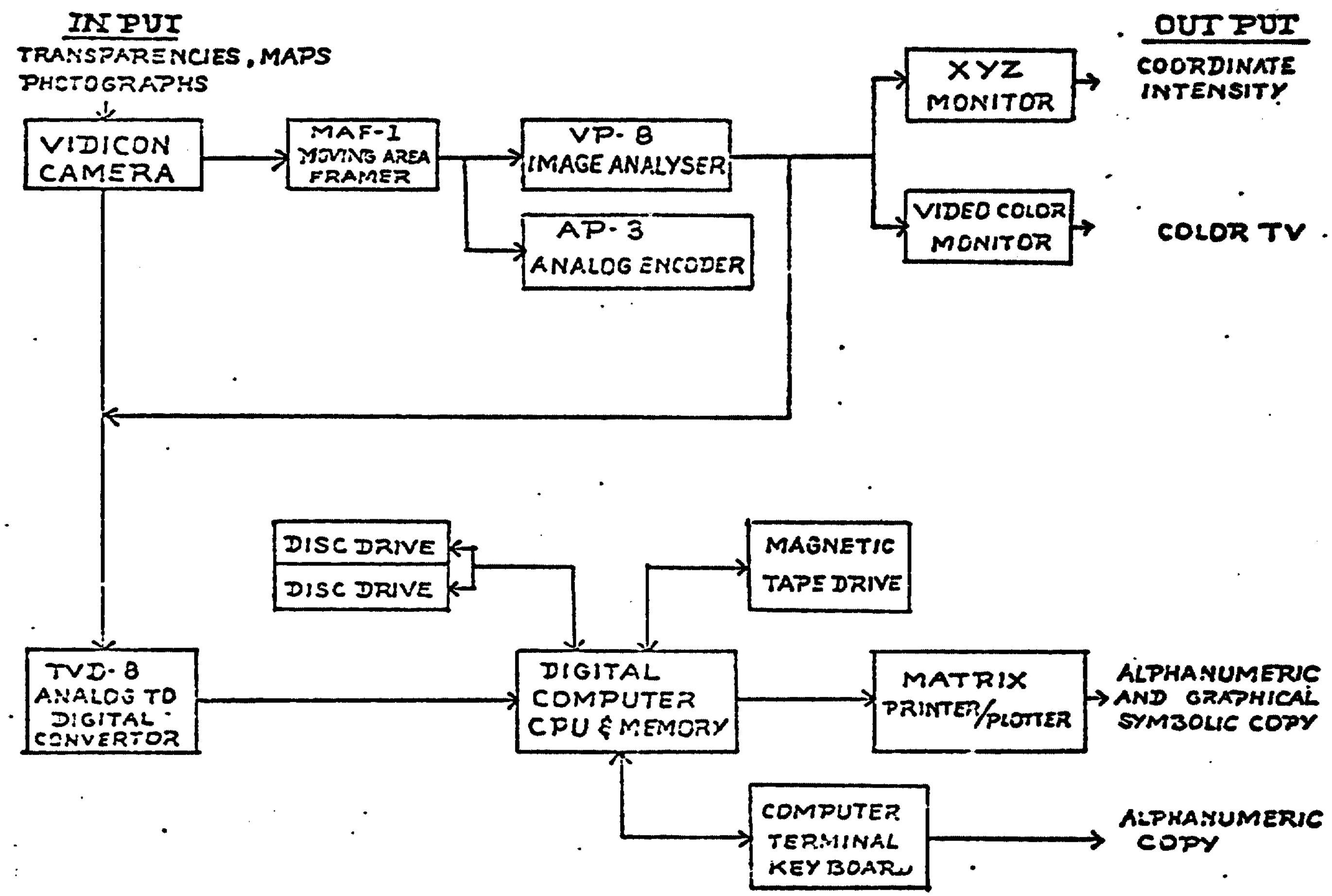

FIG.3 U.T.S.I. REMOTE SENSING LABORATORY

A modified color television set permits the user to monitor the signals produced by the camera and modified through the VP-8.

A TVD-8 Digitizer performs the analog to digital conversions necessary before the signals can be processed digitally. This unit is interfaced to the Computer by a DR-11C General Device Interface. Under program control, the TVD-8 is capable of digitizing a television image at a resolution of 480 lines by 640 columns by 8 bits. Also, specific points may be digitized as well as the coordinates (row and column) of the cursor position.

CONCLUSIONS AND RECOMMENDATIONS

Experience gained during this study could be utilized to carry out Landsat digital data analysis to a certain extent to be incorporated in Tennessee State information. The hardware system at the University of Tennessee Space Institute (UTSI) could also be made available for use to State agencies.

In order to increase systems performance at UTSI, work is required to be performed in the following areas:

(a) Software Development

Modifications in the available software at UTSI would have to be made for complete processing of Landsat data. This would include utility programs to control interfacing of hardward and also I/O routine to cover data type transformation. But as recommended by Metrics, Inc. in their report, "Design of Low-Cost Automated Data Analysis System", these modifications would be costly and probably Cal Data I (present Mini computer at UTSI) should be replaced with Data General Nova 3/12 or equivalent either by acquiring from NASA or by purchase with State funds (if available). (See reference 3.)

(b) Augmentation of UTSI Laboratory

In order to augment the existing remote sensing data processing facility at UTSI, it is suggested that the NASA NRPAS software module which is currently housed at UT-Nashville be transferred to UTSI.

(c) Completion of Entire State Analysis

To carry out Landsat digital analysis of the entire state, it is recommended that NASA-MSFC may borrow CCT's of row 35 and Paths 19 to 24 from NASA-GSFC and lend them to UTSI. UTSI would get the tapes copied at UT-Knoxville and return them to NASA.

(d) Future Planning

In the coming years more emphasis will be put on geographical and natural resources data bases, of which remote sensing data is a part. This will increase the demand for communications/computer networks to provide multi access to data files and analysis models. (See reference 4.) Therefore, in organizing a state-wide remote sensing data analysis facility these future trends should be taken into account.

References

1. Manual on Characteristic of Landsat Computer Compatible Tapes Produced by EROS DIPS.

2. A. D. Bond, et al, 1977. Digital Computer Processing of Landsat Data for North Alabama: NASA CR-2932

3. Metrics, Inc., Design of a Low-Cost Automated Landsat Data Analysis System, Final Report on NASA Contract No. NAS8-33136.

4. G. W. Spann, Satellite Remote Sensing Markets in the 1980's, Photogrammetric Engineering and Remote Sensing. Vol. XLVI, No. 1, January 1980, p. 168.

APPENDIX

TENNESSEE STATE AGENCY REQUIREMENTS FOR LANDSAT DATA

Department of Conservation

Development Planning - This division is responsible for the overall development plans for the Department of Conservation. State planning has worked with this division several times providing land use maps developed from either Landsat or aerial photos. The level of detail for these studies has been relatively small and we have used 1:24,000 maps for base data.

This division is also responsible for basin studies of scenic rivers (Hatchie River) and studies concerning natural areas among others. The data this division would need will generally fall along the following land use down to second level and possibly third level in some specific instances; type and extent of vegetative cover; point and non-point pollution; data concerning flooding, especially important in west Tennessee. Tabular data concerning acres and square miles of each class of land use will also be necessary.

Forestry Division - Their primary concern has been the health, type, geographic distribution and extent of forest cover. Work was done with this division three years ago using NASA film of the wetlands to determine the extent of damage to lowland timber resulting from water, beavers and siltation. The Forestry Division state that the use of aerial photography saved them thousands of man hours in assessing this damage. Often the tree-kill was in areas impossible to get to on foot.

Forestry's primary interest at the moment is west Tennessee where the greatest amount of forest loss has occurred because of wetlands flooding. The most obvious result of this loss is the closing of timber mills; where there once were over fifty mills in west Tennessee there are now less than thirty-four.

This division would make use of land use maps and forest-type maps down to second level. Of particular interest in their field would be the ability to note the increase or decrease in forest types through a period of time. They could also make use of tabular data similar to those provided for the river basin land use maps.

Geology Division - Geology does have a browse file but they have no one familiar with remote sensing. In addition to the various geologic data that can be derived from Landsat, they would be interested in lineament studies, analysis of faults, and filing of thousands of records, data and information presently lying around in piles on the shelves, files and on the floors.

The division of geology probably produces a high percentage of technical reports for the state and for general distribution. Landsat could be used in generating data for these reports but geology would have to specify what their needs would be.

Surface Mining and Orphan Land Reclamation Division - These two divisions are grouped together because they are concerned with monitoring surface mining. The first division is concerned with the permit procedure for surface mining and then monitoring the mine activity after the permits are issued. Recently with the passing of new mining rules and regulations, "wildcat mining" has become quite common. A great example was a large surface mine that was worked for several months on state land unknown by anyone, including the state.

Surface Mining Division needs a method of monitoring these mines other than placing people on the site. They also need a method of monitoring wildcat mines, i.e., noting when they first begin their activity and then to monitor them if they continue their activity.

Orphan Land Reclamation is concerned with "after the fact" activity. Their concern is making sure the mined-over land is reclaimed to specifications, that vegetation is introduced and that it is maintained.

Both divisions approach the possibility of Landsat monitoring with the questions of (1) how much is it going to cost and (2) what is the smallest area you can monitor. Their past budget has been such that they could not even purchase TVA photographs of surface mines for monitoring. This may change if the constant rumbling about federal money appropriated for surface mining does prove to be true.

Water Resources Division - This division has a ton of data and information all of which is six to eight years out of date. The majority of this material concerns well-water logs and water quality/quantity maps developed from these logs.

There is little that Landsat could do in providing data for this division. However, there is much that could be done in the storage/retrieval area for the data they now have.

Economic and Community Development Department - One of the more important jobs of E&CD is bringing industry to the state. They also compile reports of economic data that can be distributed to those needing information concerning the state. Landsat could easily provide several types of physical data to this department which would include among others land use, geology, urban patterns and surface water problem detection. The data base should be broken into different categories so that, for example, if forest information is needed, such information as has been gathered for the Division of Forestry could be provided directly to E&CD.

If a conference were held in the state for prospective industries, E&CD could depend upon TSPO for real-time retrieval of data needed for the conference. (This same type of on-line provision of physical data for conferences could be provided for several other state agencies).

Department of Public Health

Air Pollution Control - The Air Pollution Group is concerned with monitoring air quality, specifically in highly industrialized or urbanized areas. A case in point would be the monitoring of the carborundum plant at Jacksboro. If air quality could be monitored from Landsat it would provide data other than that gathered from ground instruments.

Water Quality Control Division - TSPO has provided a state-wide second level land use map for this division as part of the state 208 water quality plan. Land use is of interest to this division as one of the characteristics affecting water quality. They would be interested in spotting and monitoring non-point pollution sources as well as the effects of this pollution.

Solid Waste Management Division - This division is concerned with maintaining specifications for solid waste dumping areas. These often are wildcat dumping areas and their problems are similar to those of Surface Mining. A spinoff of these wildcat dumping areas is often water pollution; the problem then becomes one for Water Quality as well as Solid Waste.

Department of Transportation - DOT has several bureaus and divisions that could make use of Landsat data and Probably the one needing this data the most is the Bureau of Planning and Programming. This type of analysis would alleviate several of the negative comments that they so often receive on a proposed project if they would incorporate the data into their design plans. A perfect example might be the following:

The great River Road in west Tennessee, roughly paralleling the Mississippi River, has been in the planning stage for years. Both the Department of Conservation and the Wildlife Resources Agency have been concerned with the road because it will cross several of the tributaries of the Mississippi (Hatchie and Obion-Forked Deer). Their contention is the various bridges and road fills would result in detrimental environmental effects in addition to contributing to flooding problems, especially in the spring. The Water Quality Division would have some interest in this problem because there are certain criteria of water quality that must be met during and following construction. At present, reviews are made after the complete plan is drawn up. Much planning detail then is struck out and goes to waste. All of this could be alleviated through coordination of data gathering from the various agencies.

There should be a centralized data system/source for this type of coordination. There is none at the moment and there is some doubt that DOT would want to depend upon one.

DOT has the Bureau of Aeronautics. They have some aerial photography at their disposal, but their use of them has been limited to study of state road right-of-way. It might be possible for their aircraft and equipment to be available for remote sensing.

Wildlife Resources Agency

Although many functions of this agency seem to parallel the Department of Conservation their functions may be divided as follows: TWRA takes care of "birds and bunnies", Conservation takes care of non-animal populations. They, like almost every state agency, have a division of Planning and Environmental Services. Any physical data gathered by Landsat would essentially meet the same requirements as those of the Department of Conservation.

State Planning Office, Local Planning Office and Nine Development Districts

The functions of these agencies overlap in several areas but all can make use of Landsat's land use mapping capability. The problem here is that Local Planning wants the land use unit on the smallest unit possible. Since the development districts work with multi-county areas their units of concern are slightly larger. State Planning, of course, maps land use according to whatever scale is needed.

A related problem is that there seems to be no set map scale or land use qualifications. Upper east Tennessee might map their development district at a scale of 1:125,000 and use six land use elements. Mid-Cumberland might map at 1:250,000 and use ten land use elements. More often than not the scale is determined by the size of a sheet of paper in the final report. Land use elements are picked by the locals; there is very seldom any refernece to a USGS Circular 671 put out by James R. Anderson at Interior or any other type of land use system.

The primary objection to Landsat by Local Planning and the development districts is cost and they cannot see any practical use for it at their level of concern.

Federal Agencies

In addition to the several state agencies previously noted, federal agencies such as the Soil Conservation Service could make use of Landsat data in coordinating their various activities with those of state agencies. This may be an extremely different area to examine but it does warrant some attention.

Comptroller's Office

The Tax Equalization Board that is under this office houses tax maps for the state. In addition they also house aerial photos on a couty-wide basis although coverage of the state is imcomplete. These photos seem to be SCS photos and range in scale from 1:6,000 to 1:12,000 for individual photos to 1:125,000 for mosaics of the whole county. The only possible use of Landsat derived data in this department would be for having access to complete coverage of the state for county mosaics. (There have been some suggestions from Dr. Peplies of East Tennessee State Univeristy to use the tax maps as a basis for a state-wide land use system, but this would be off in the future.)

There are several ways that the state could be approached about putting together a Landsat system. On the fiscal side of the issue, it makes little or no sense to have as many state agencies as are listed herein either using Landsat or having the potential of using the system without some form of coordination. From that standpoint, it is less expensive to have everyone throw some money in one fund rather than funding several separate, though related programs. Many of these programs are also related to federal programs so if there isn't duplication of effort, it is at least quasi-duplication.

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
IN COOPERATION WITH
THE TENNESSEE ASSOCIATION OF CONSERVATION DISTRICTS

[illegible]

LAND U

WEST T

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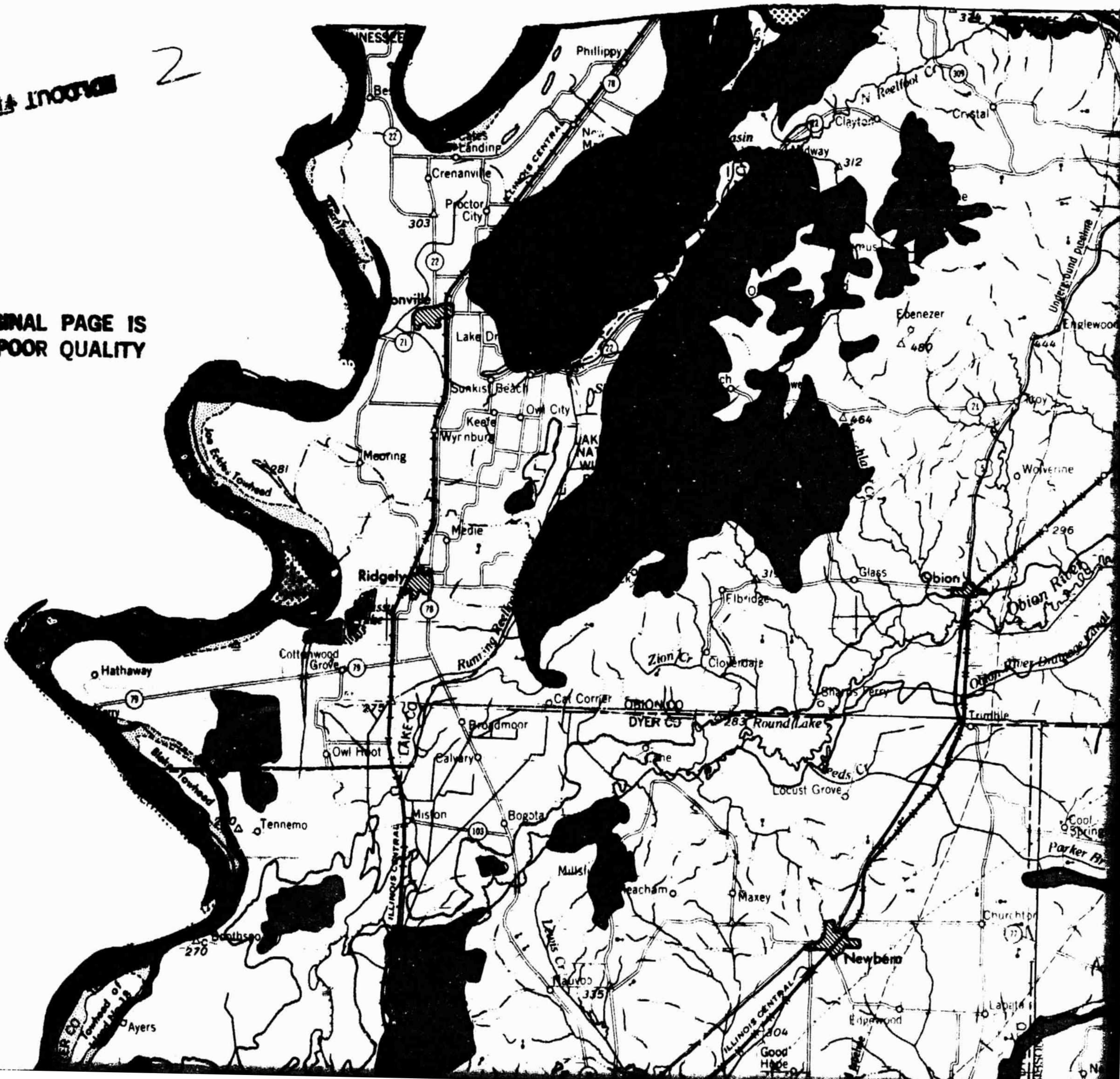


LAND USE MAP
OF
WEST TENNESSEE

FOLDOUT FRAME 3

FOLDOUT FRAME 4

Figure 1

FINAL REPORT; Contract #

DIVISION OF REMOT
THE UNIVERSITY OF TENNESS
TULLAHOMA, TEN

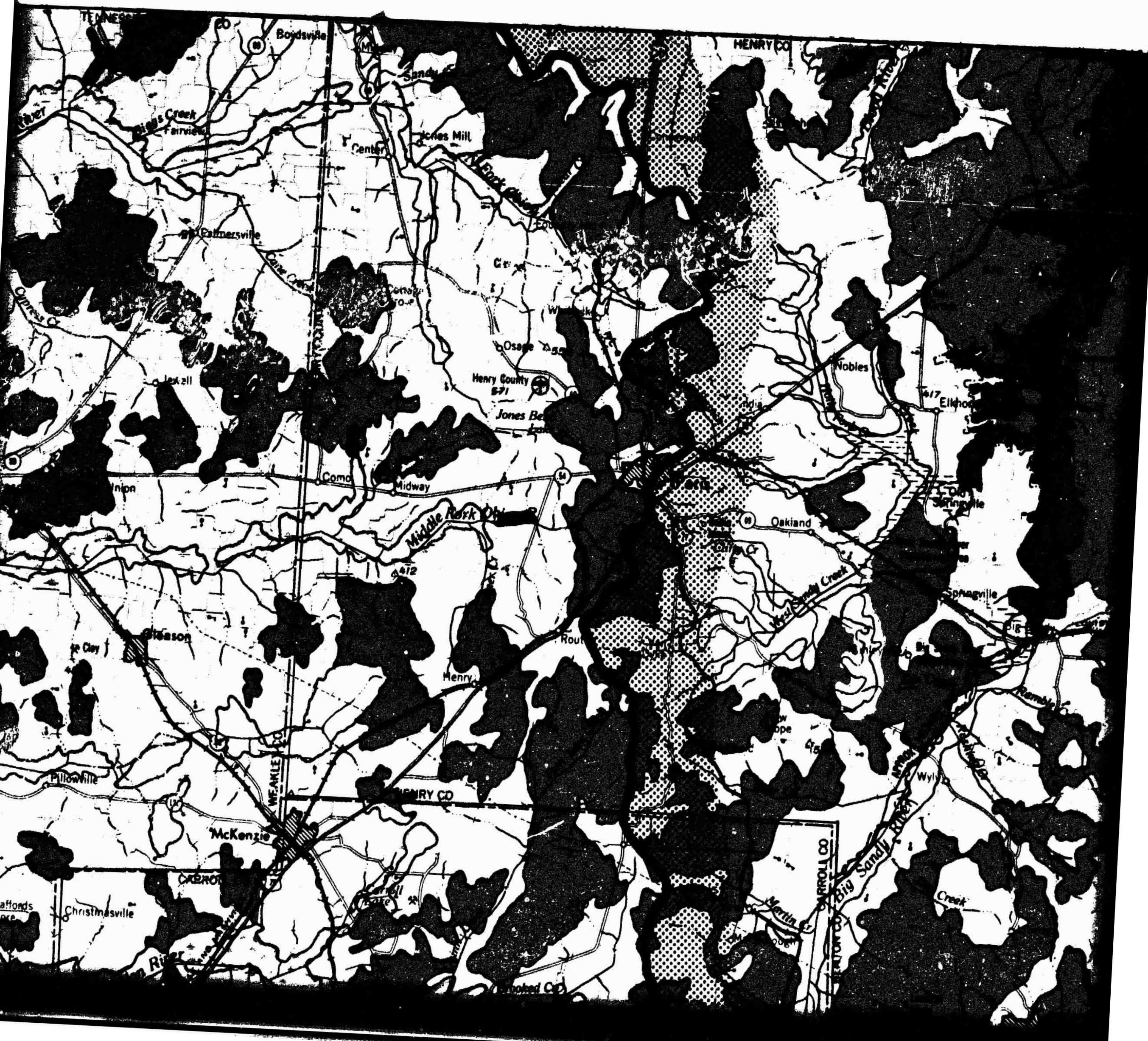
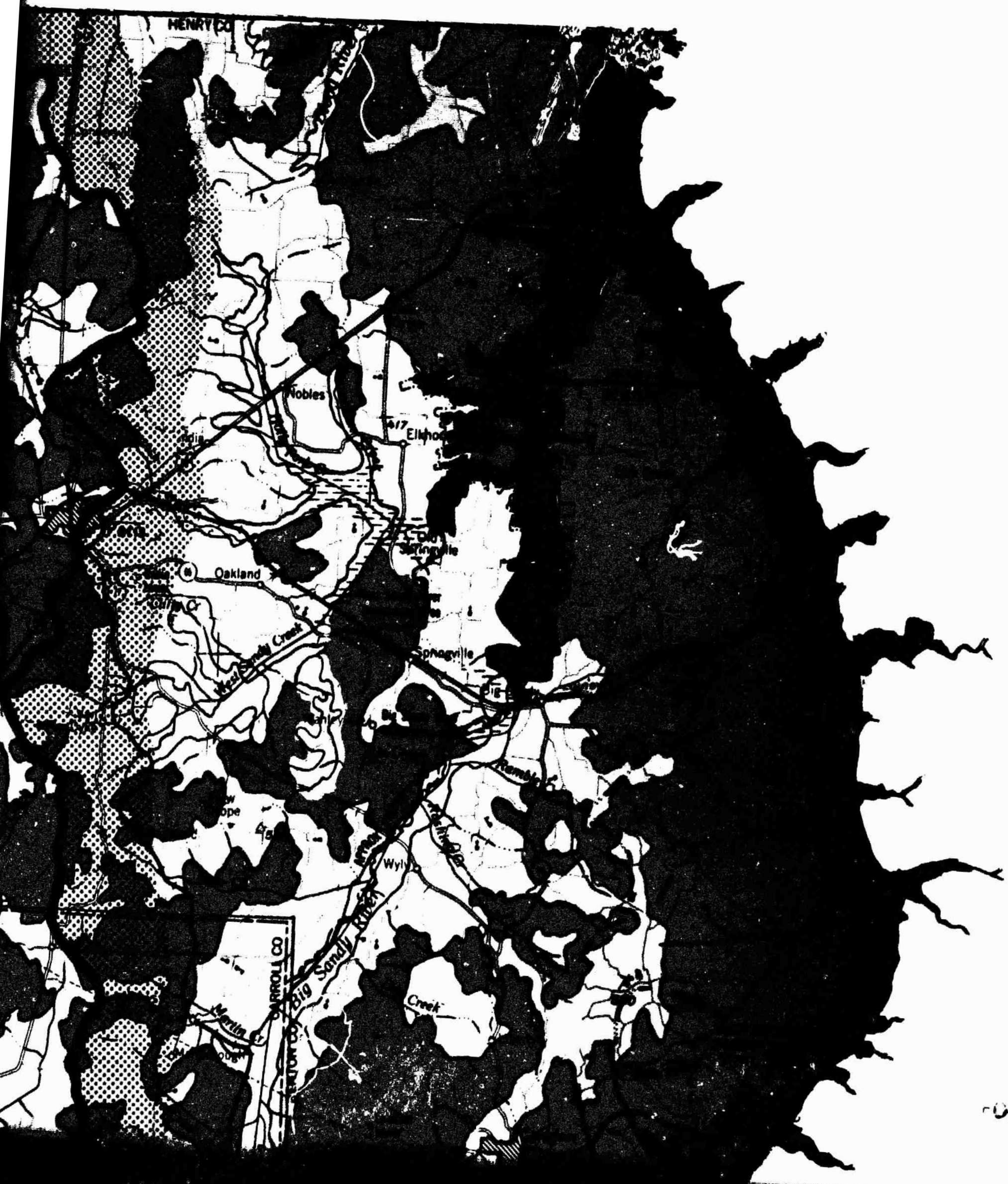


Figure 1

FINAL REPORT; Contract #NAS8-33218

DIVISION OF REMOTE SENSING
THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE
TULLAHOMA, TENNESSEE



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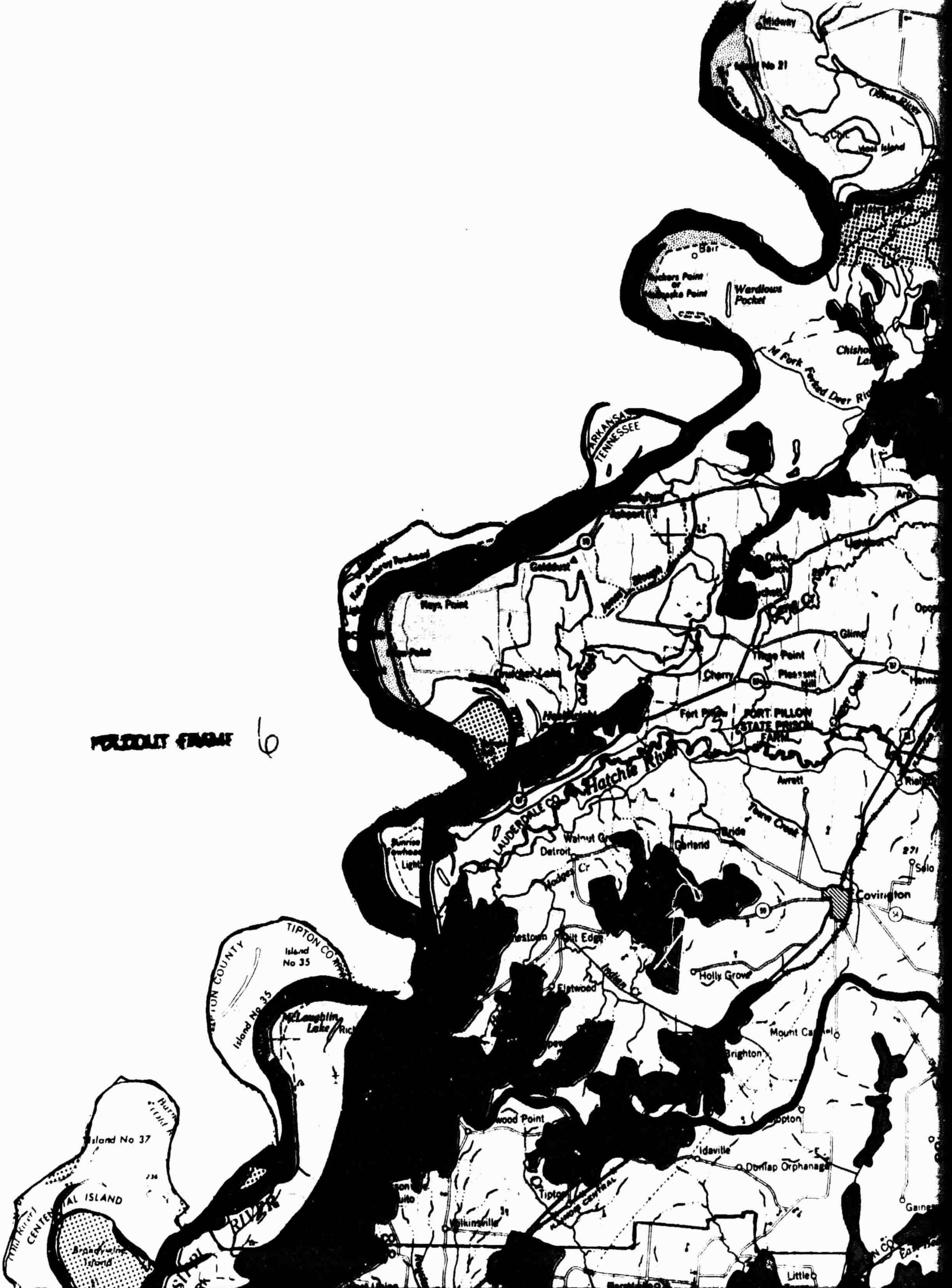
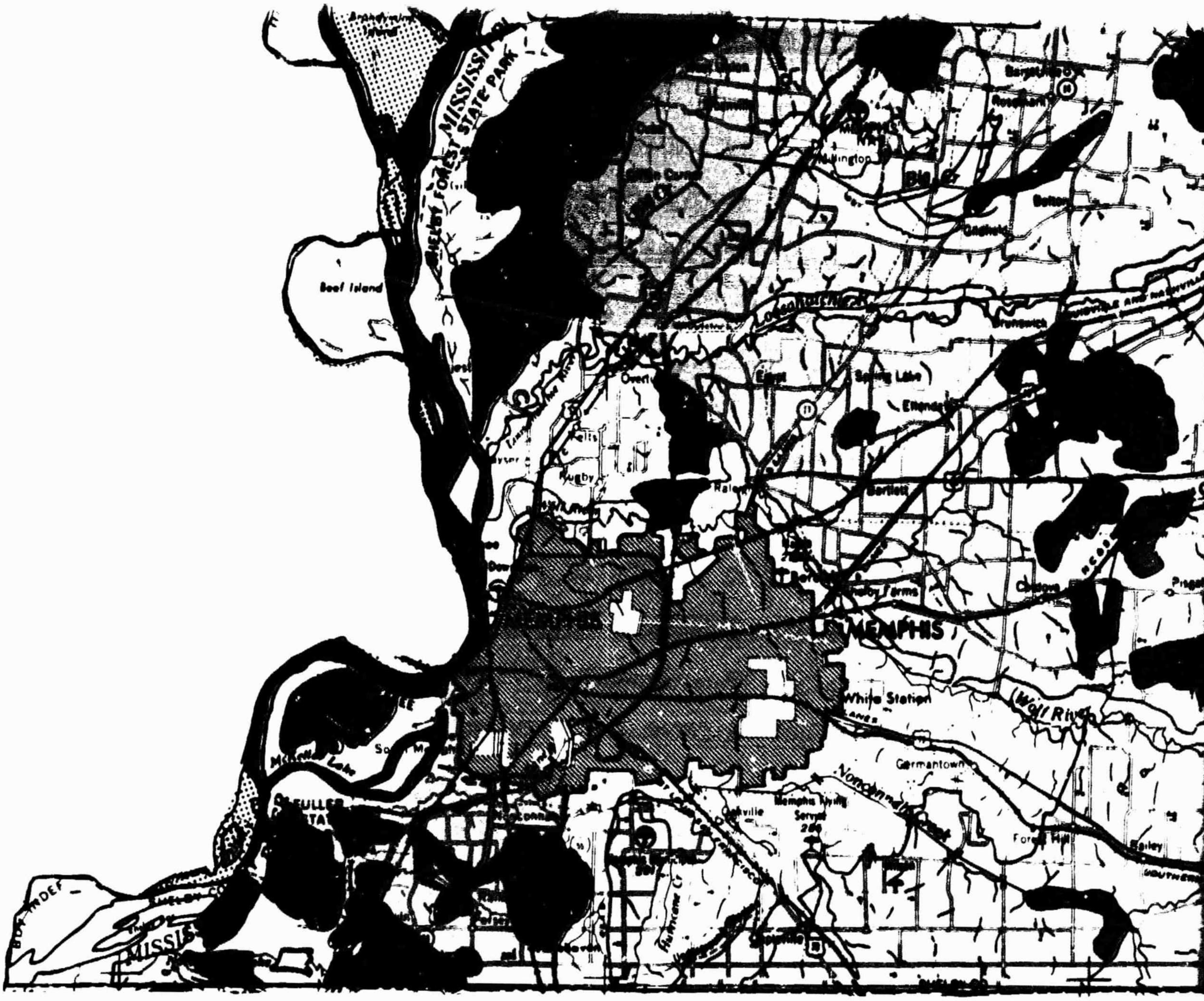



Central
Trenton
Four Points
Eaton
Elizabeth
Bonicord
Tigrett
Stokes
Unionville
LAUDERDALE CO
South Fork
Brazil
Friendship
Double Bridges
Old Gibson Wells
Chestnut Bluff
Crockett Mills
Dog Hill
Broadview
Pond Cr
Cairo
Quincy
Nance
Conville
Humboldt Lake
Maury City
Elmore
Cypress Cr
Alamo
Gadsden
Forked Deer
Johnsons Grove
Mason Grove
HAYWOOD CO
Bethel
Cross Road
Fruitvale
Bells
Walnut Hill
Rudolph
Christmasville
Belle Eagle
Poplar Corner
Holly Grove
Providence
Durhamville
Allens
Wellwood
Huntersville
Hatchie River
Hatchie Bottom
Sunnyhill
Shaw Lake
Stanton
Koko
Hillville
Antioch
Spring Hill
Hatchie
HARDEMAN CO
Keeling
Dancyville
Cloverport
FAYETTE COUNTY
HAYWOOD
Belmont
Campground
Gamble Branch
Hatchie River


Central
Eaton
Elizabeth
Trenton
Brant
Edison
Fruitland
Old Gibson Wells
Gibson
Milan
Lavinia
Quincy
Nance
Cairo
Pond Cr
Humboldt Lake
Humboldt
Humboldt Municipal
Medina
MADISON COUNTY
Cypress Cr
Alamo
Gadsden
Mason Grove
Cross Road
Fruitvale
Windy City
Young Crossing
Carroll
Oakfield
Bells
Walnut Hill
Jones
Poplar Corner
Holly Grove
Providence
Huntersville
Allens
Wellwood
Westover
South Fork Forked Deer River
Beech Bluff
Five Points
Shaw Lake
Hatchie Bottom
Hillville
Hatchie
HARDEMAN CO
Cloverport
Hatchie River
Gamble Branch
Montezuma
CHESTER CO

FOLDOUT FRAME 9

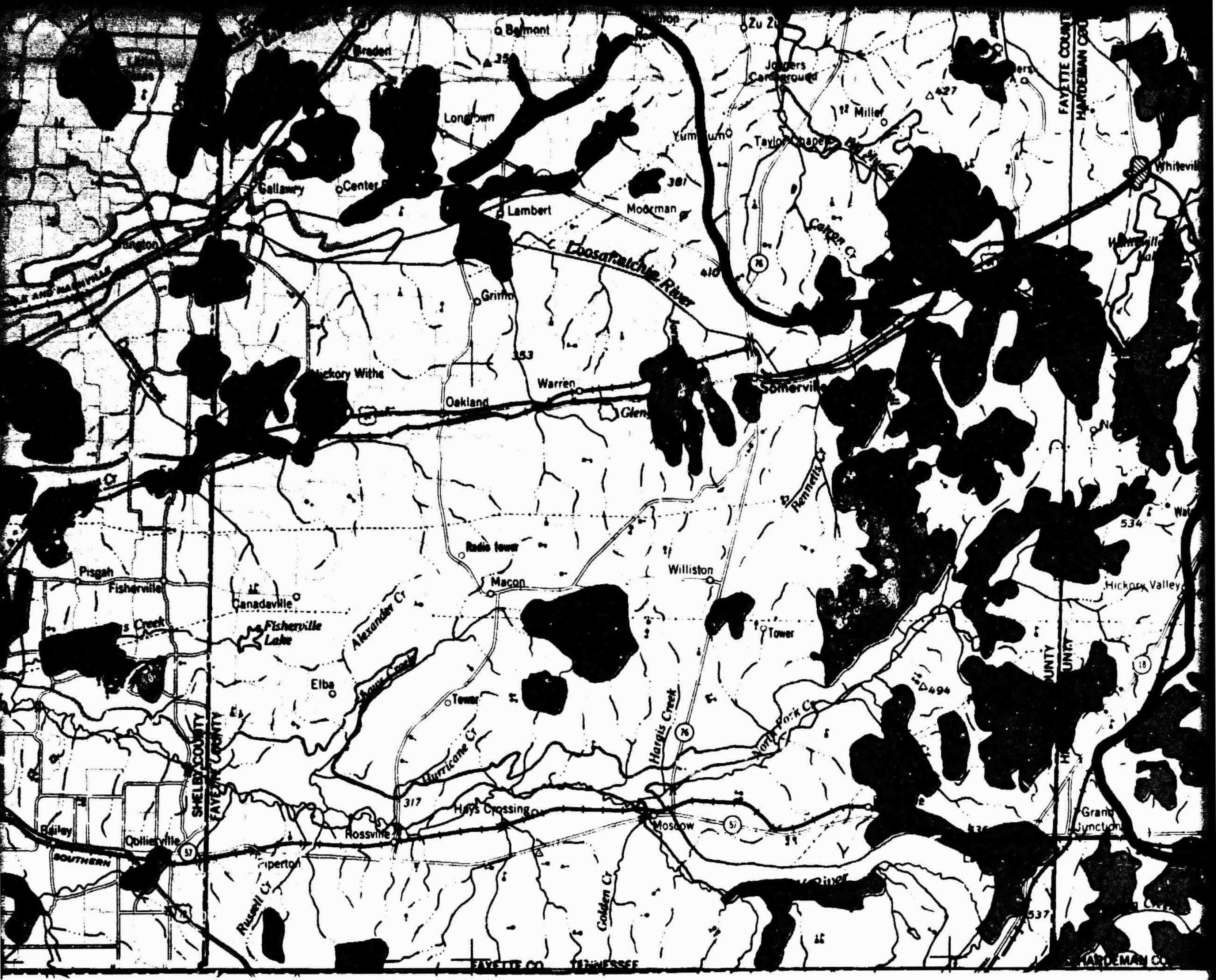


FOLDOUT FRAME 10

LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA ADAPTED FROM ANDERSON'S SYSTEM OF LEVEL I CLASSIFICATION REF: U. S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 964, WASHINGTON, D.C. 1976

Land use data compiled from Land-Sat Images taken in February 1979.

Developed jointly by Remote Sensing Division, The University of Tennessee Space Institute, Tullahoma, Tennessee 37388 and Soil Conservation Service USDA, Nashville, Tennessee



Key Map

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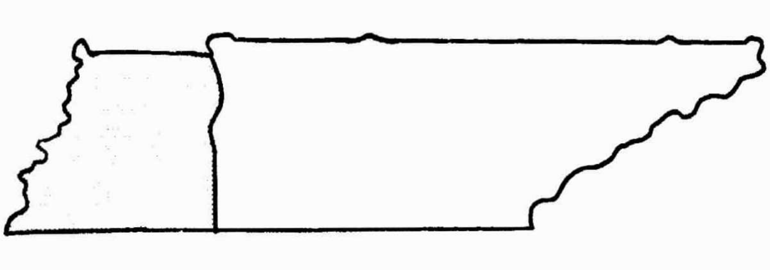
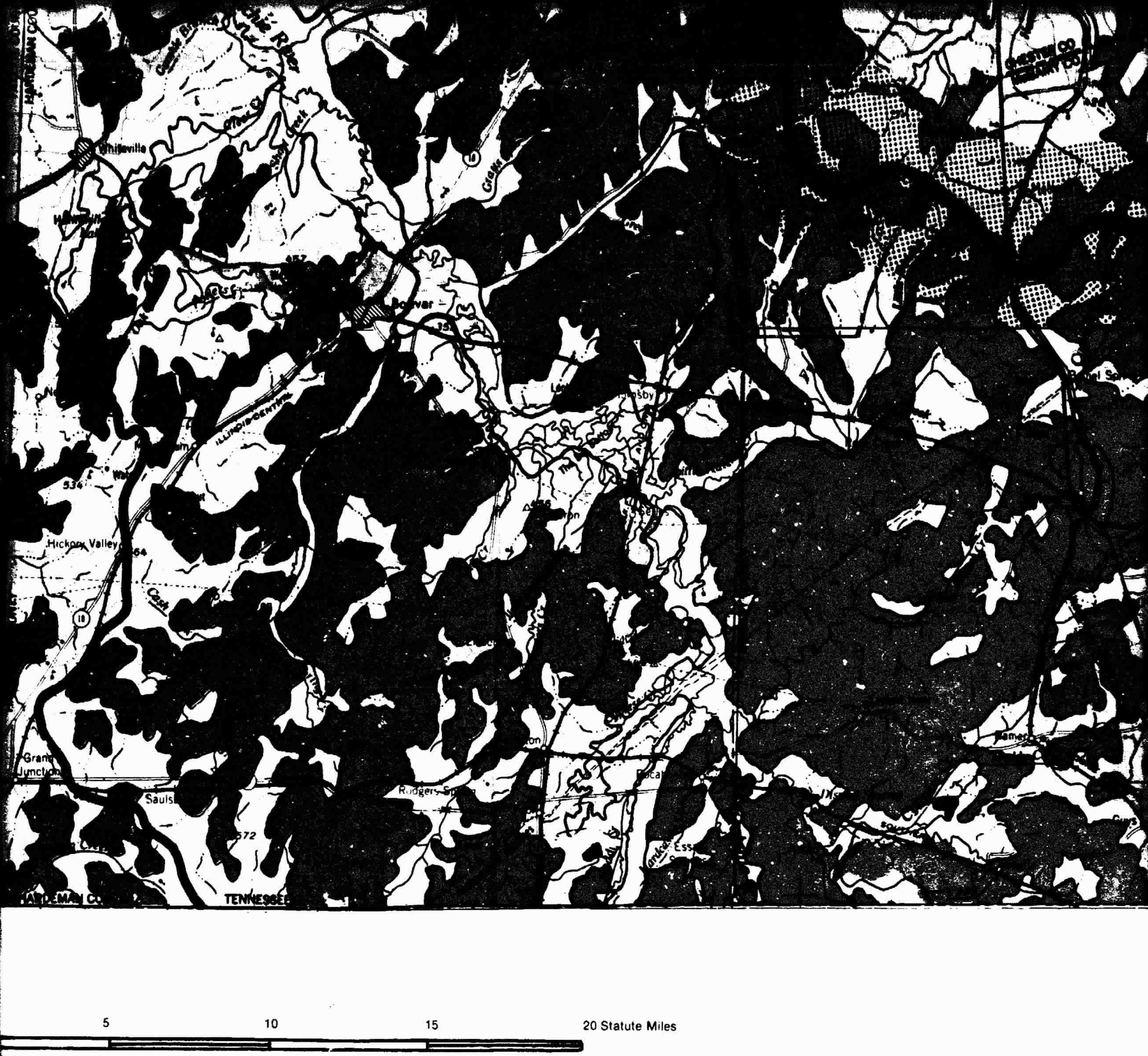
SCA



Map Published in July 1979.

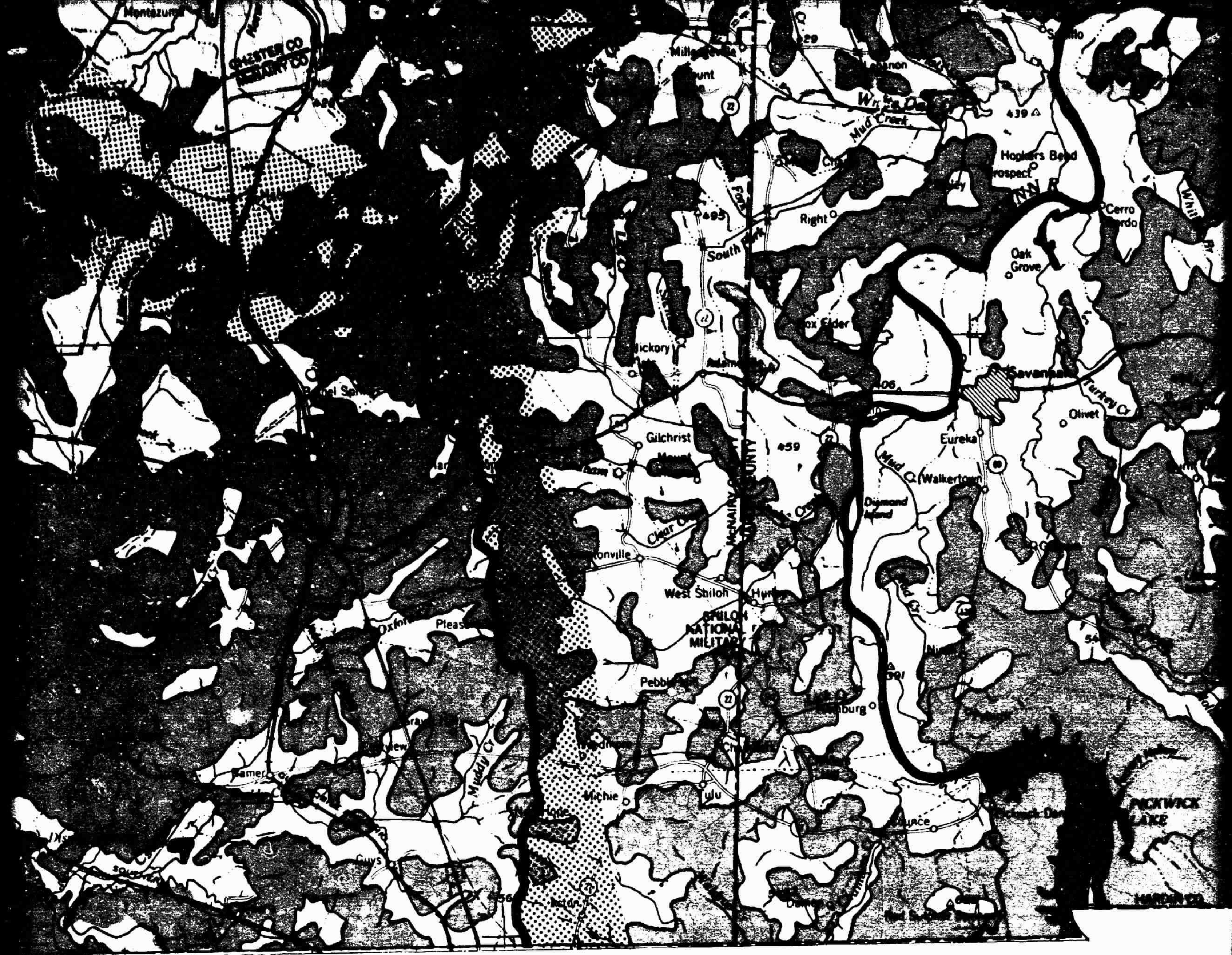


SCALE 1:250,000

LAND USE

- URBAN OR BUI
- AGRICULTURA
- FOREST LAND
- WATER
- SEASONALLY

FOLDOUT FRAME 12



LAND USE CLASSIFICATION CATEGORIES

- URBAN OR BUILT-UP LAND = 169 Sq. Miles
- AGRICULTURAL LAND = 6,320 Sq. Miles
- FOREST LAND = 3,041 Sq. Miles
- WATER = 285 Sq. Miles
- SEASONALLY FLOODED LAND = 900 Sq. Miles

N

EGORIES

N

9 Sq. Miles

0 Sq. Miles

1 Sq. Miles

5 Sq. Miles

0 Sq. Miles

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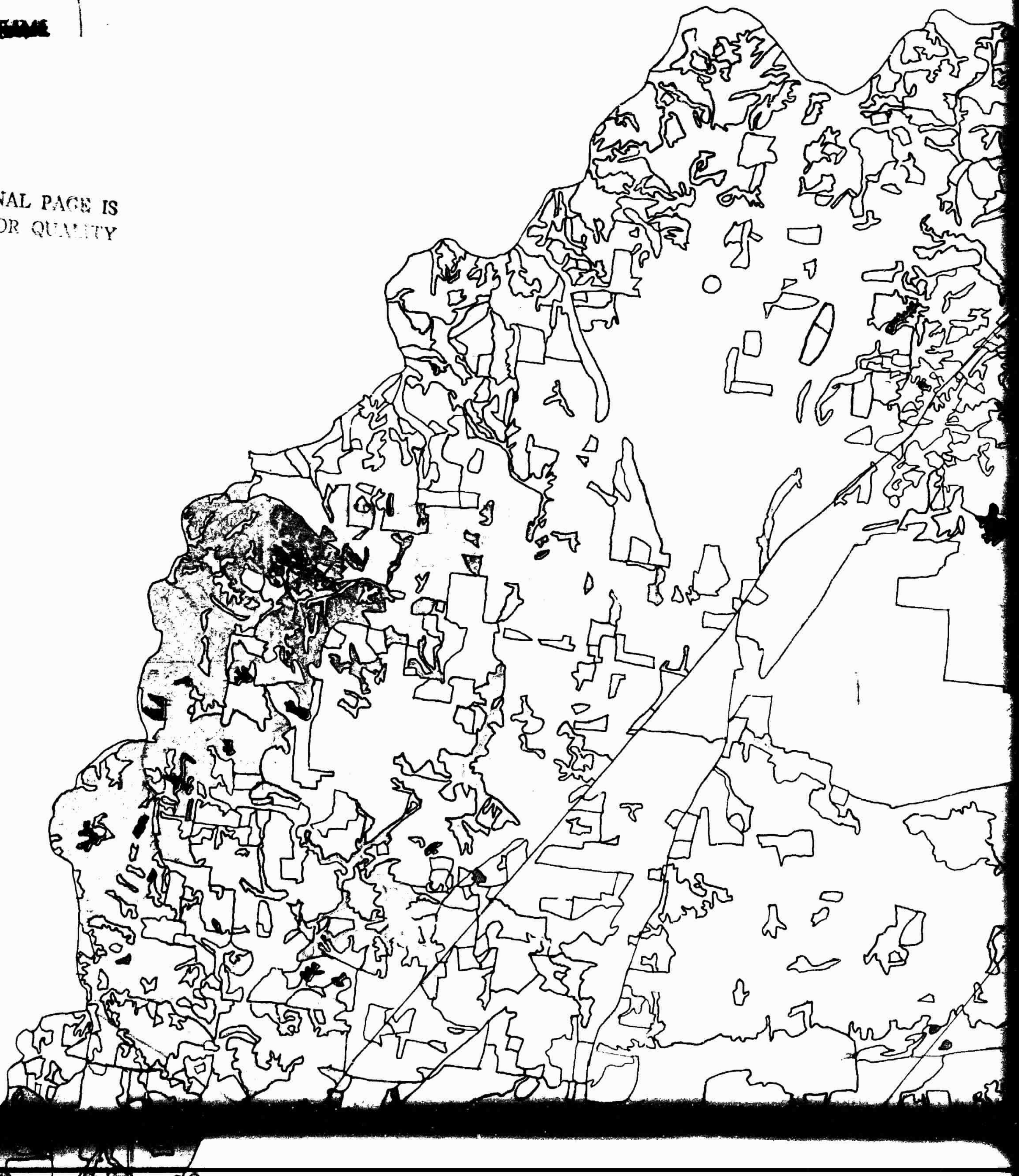
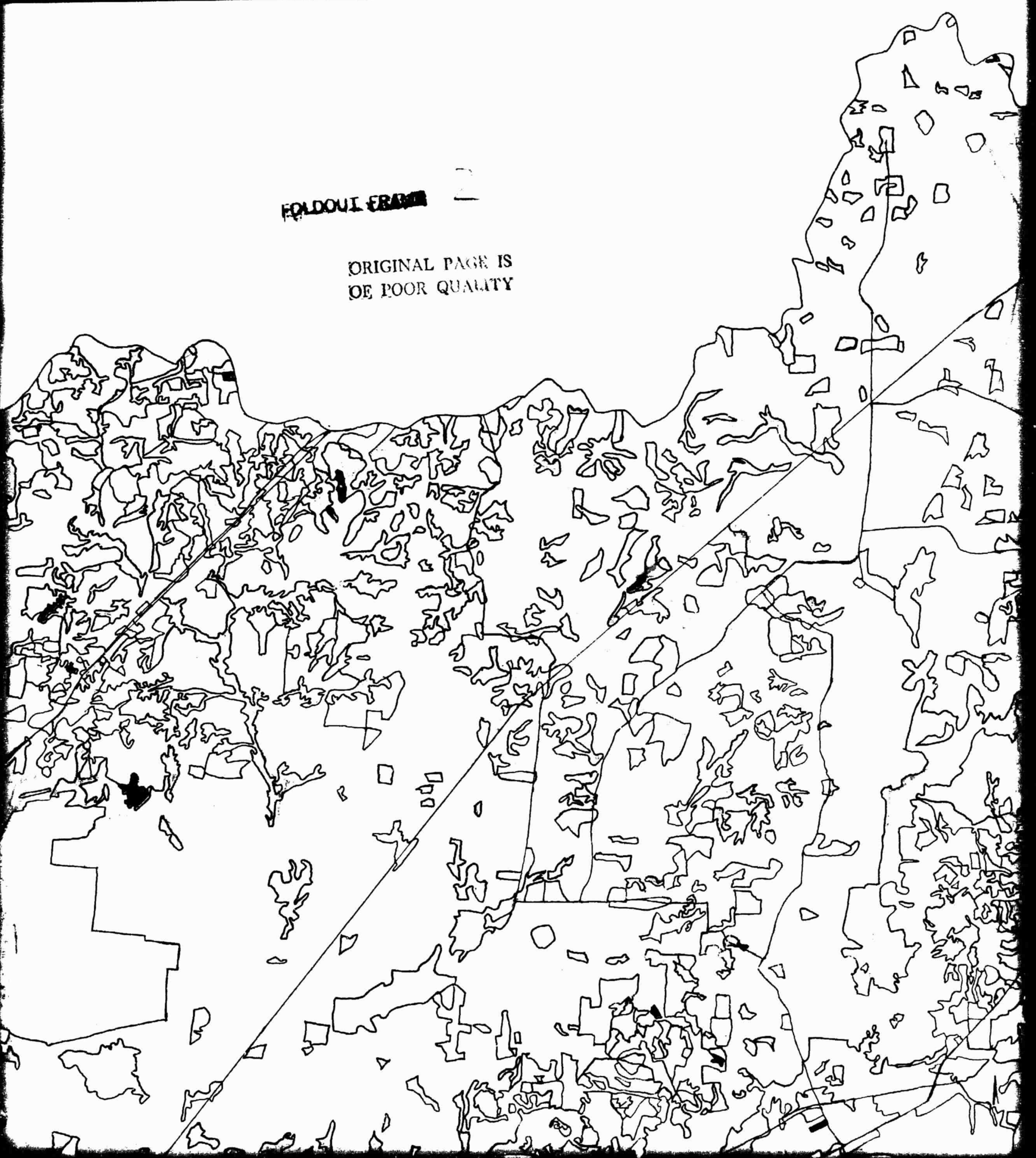
UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
FOREST SERVICE
ECONOMICS, STATISTICS, AND COOPERATIVE SERVICE

FOLDOUT FRAME

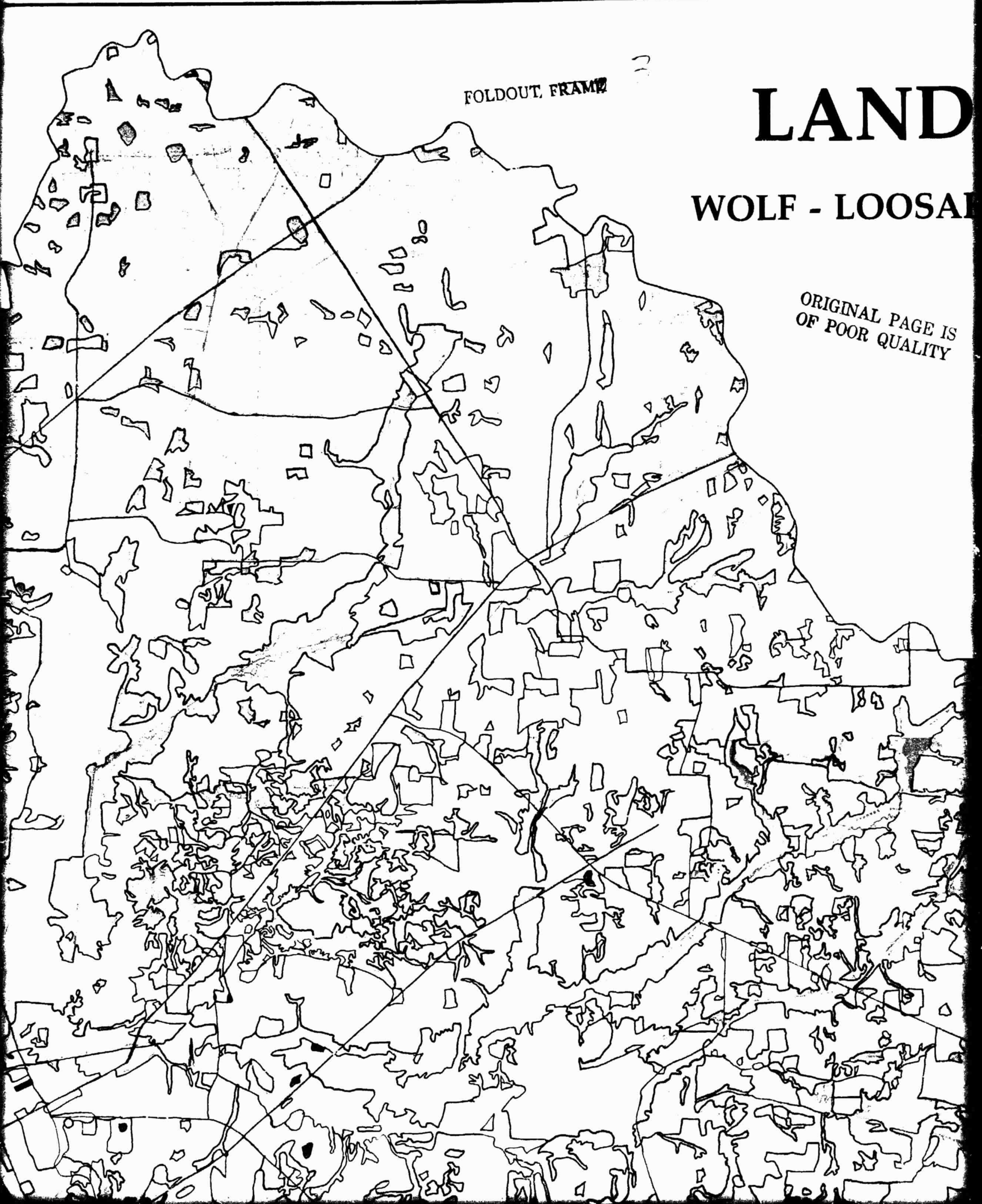


FOLDOUT FRAME 2



LAND

WOLF - LOOSA



ND USE MAP

OOSAHATCHIE RIVER BASINS

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Figure 1

FINAL REPORT; Contract #NAS8-33218

REMOTE SENSING DIVISION
THE UNIVERSITY OF TENNESSEE SPACE INSTITUTE
TULLAHOMA, TENNESSEE

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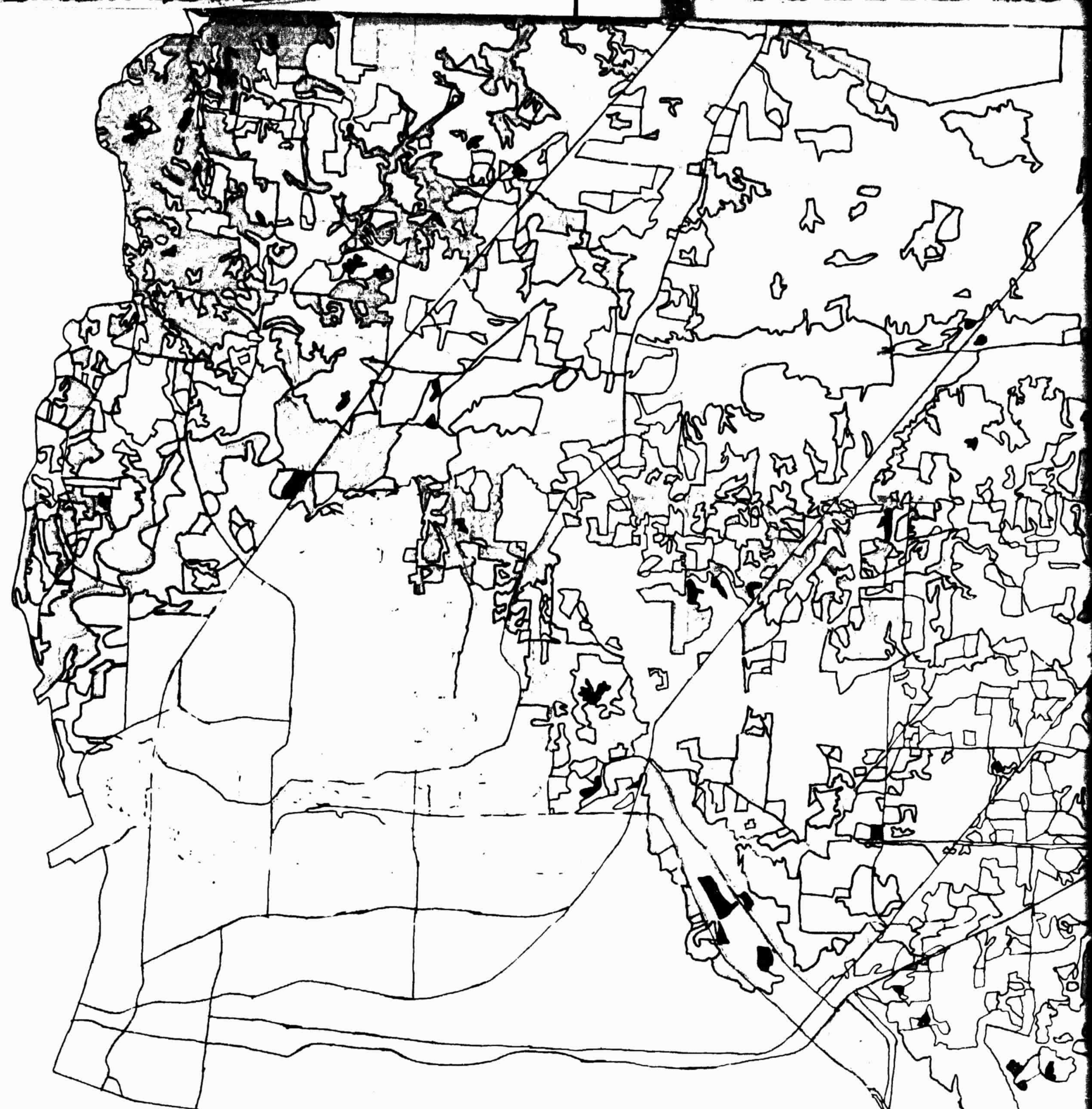
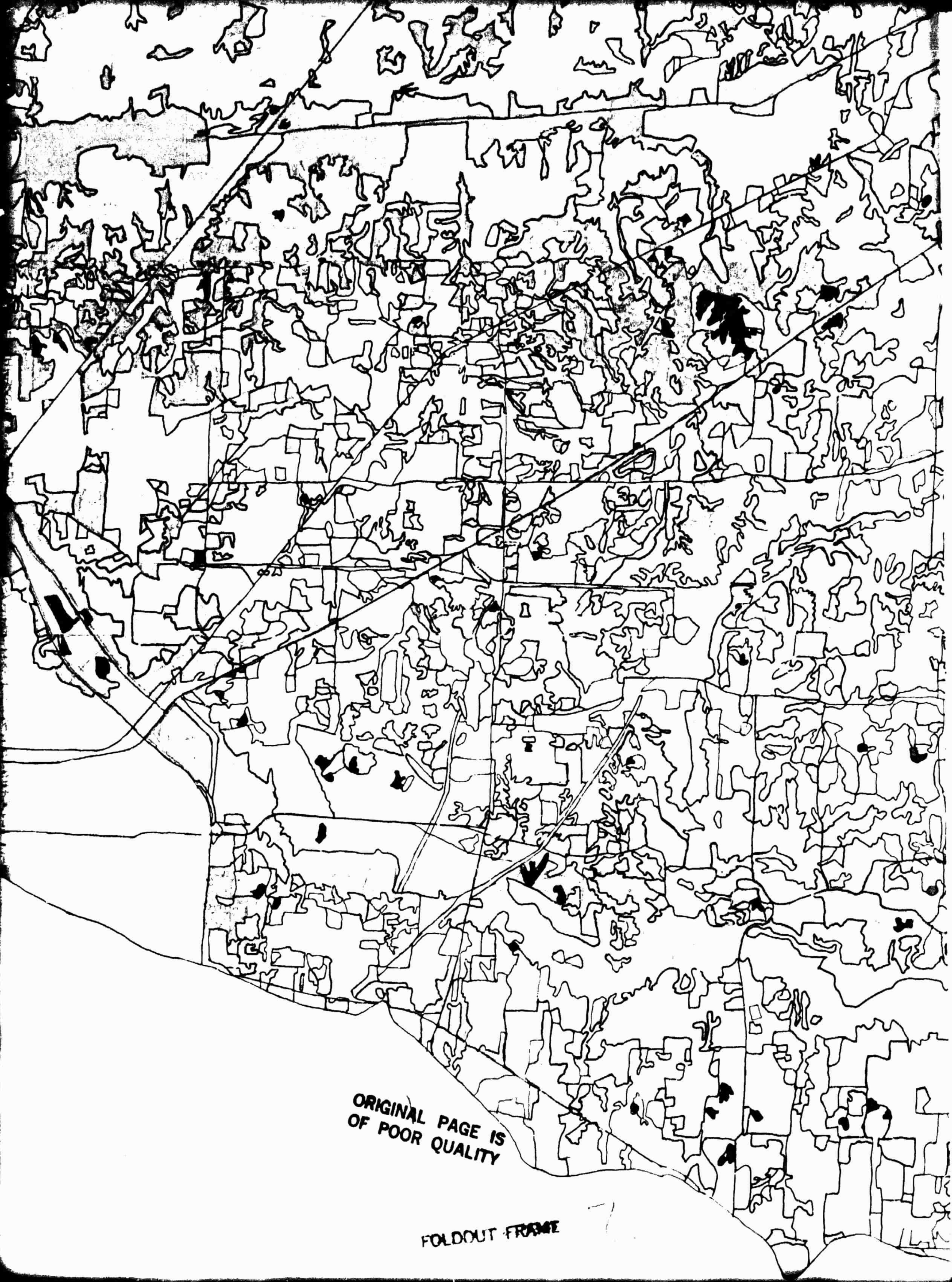




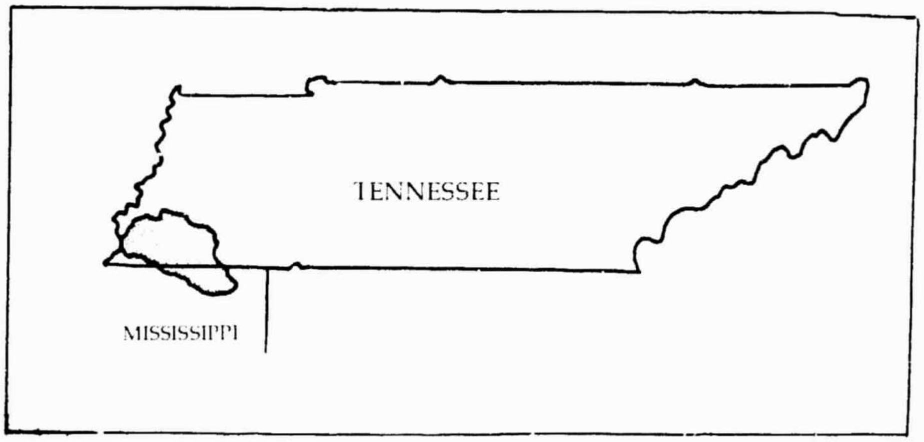

FOLDOUT FRAME 3

?LDOUT FRAME

LAND USE MAP COMPILED FROM
AERIAL PHOTOGRAPHS TAKEN IN SEPTEMBER, 1976

Developed jointly by Remote Sensing Division,
The University of Tennessee Space Institute, Tullahoma,
Tennessee 37388 and Soil Conservation Service
USDA, Nashville, Tennessee

Key Map



Map Published in January 1979.

LAND

CROPLAN

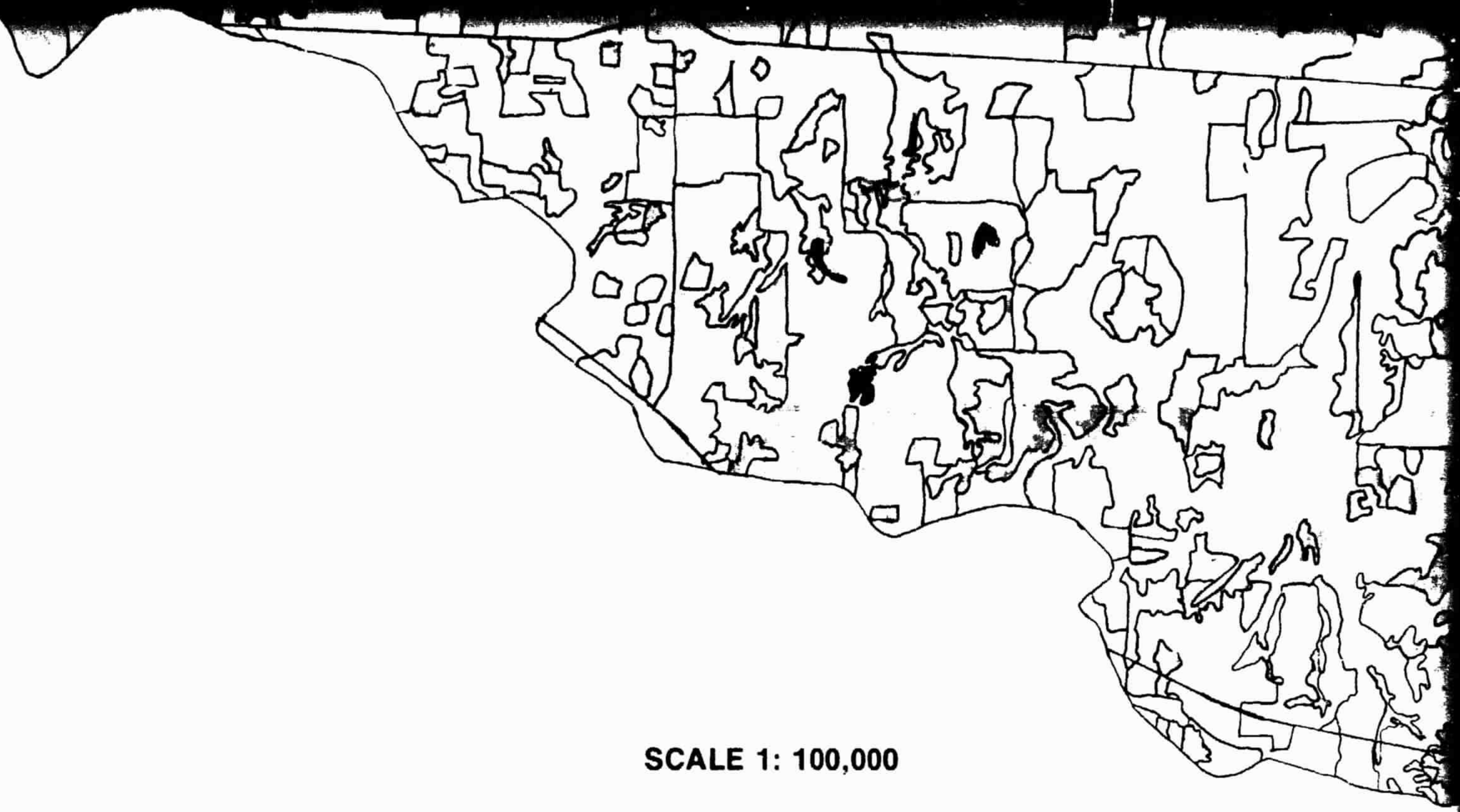
WOODLA

GRASSLAN

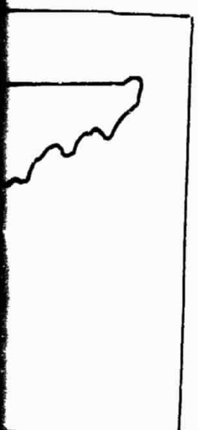
RESIDENTI
COMMERC

LAKES & F

OTHER US

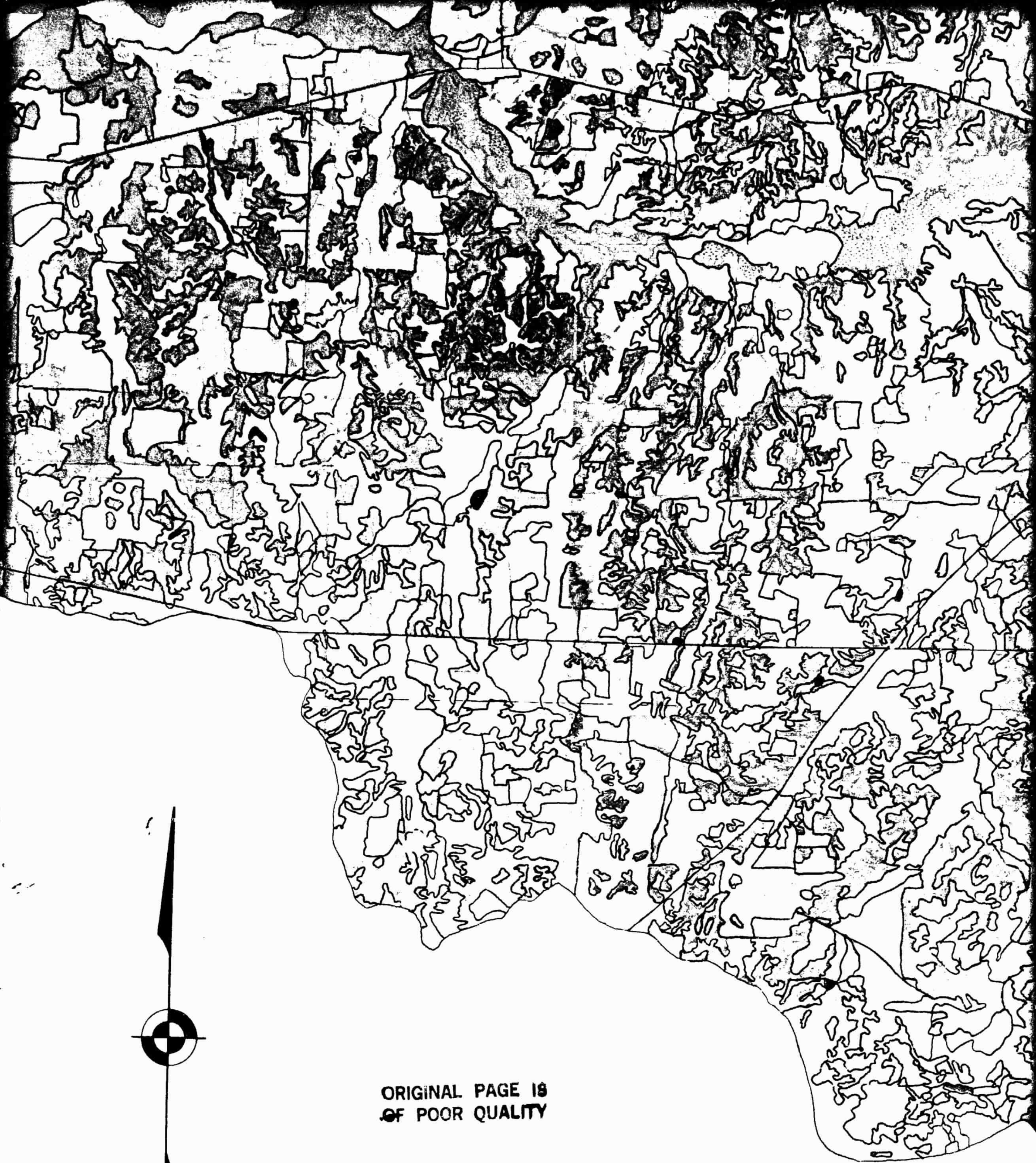


SCALE 1: 100,000



LAND USE CLASSIFICATION CATEGORIES

☐	CROPLANDS	= 431,977 Acres
☐	WOODLANDS (mixed hardwoods and conifers)	= 305,219 Acres
☐	GRASSLAND	= 161,632 Acres
☐	RESIDENTIAL, INDUSTRIAL AND COMMERCIAL	= 77,744 Acres
■	LAKES & PONDS	= 2,943 Acres
☐	OTHER USE	= 15,485 Acres



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